Expert Systems with Applications 38 (2011) 12891–12899

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Using the FDM and ANP to construct a sustainability balanced scorecard for the semiconductor industry

Chia-Wei Hsu [a], Allen H. Hu [b,*], Cherng-Ying Chiou [c], Ta-Che Chen [b]

[a] Department of Environmental Management, Tungnan University, 152, Sec. 3, Beishen Rd., Shenkeng Dist., New Taipei City 22202, Taiwan, ROC
[b] Institute of Environmental Engineering and Management, National Taipei University of Technology, Taipei, Taiwan, ROC
[c] Department of International Trade & Logistics, Overseas Chinese University, 100, Chiao Kwang Rd., Taichung 407, Taiwan, ROC

ARTICLE INFO

Keywords:
Sustainability balanced scorecard
Semiconductor industry
Fuzzy Delphi method
Analytic network process

ABSTRACT

This paper proposed a sustainability balanced scorecard (SBSC) framework to measure the sustainable performance of the semiconductor industry. Based on the principle of four perspectives of balanced scorecard (BSC), of which two were changed from the financial and customer perspectives to sustainability and stakeholder perspectives to deal the insufficiently addressed issue of corporate social responsibility. Twenty-five measures of sustainable performance were recognized through expert questionnaires and through the fuzzy Delphi method (FDM). Further, the relative weights of the selected measures were determined using the analytic network process (ANP). Results indicated that the five most important measures of sustainable performance were profitability (0.2528), green innovation and investment (0.1563), green image (0.1546), customer satisfaction (0.0799), and sustainability awareness of the top management (0.0516). Among these measures, the top three all belonged to the sustainability perspective, which comprised 56% of the overall weighting. The proposed SBSC framework can help Taiwanese semiconductor companies enhance their competitiveness in terms of sustainable operations is anticipated.

1. Introduction

Businesses are increasingly becoming interested in corporate social responsibility (CSR). The performance evaluation of enterprises has shifted from the conventional financial performance within a single dimension to a triple bottom line (TBL) performance within multi-dimensions. In view of the importance of addressing the issue of sustainability in performance assessments, various studies (Atkinson, 2000; BSI, AccountAbility, & Forum for the Future, 2001; Dias-Sardinha & Reijnders, 2005) have launched different models for measuring and managing sustainable performance. Considering the properties of periodic and systematic system controls in the strategic management of sustainability, the balanced scorecard (BSC) has widely been applied in assessing the environmental and social performance of companies (Bieker & Waxenberger, 2002; BSI et al., 2001; Dias-Sardinha & Reijnders, 2005; Epstein & Wisner, 2001; Figge, Hahn, Schaltegger, & Wagner, 2002; Gminder & Bieker, 2002; Hockerts & O'Rourke, 2002; Johnson, 1998). As pointed out by Epstein and Wisner (2001), the BSC is adopted by corporations throughout the world to help them implement corporate strategy. Moreover, it can be used by organizations to implement sustainable strategies and to link corporate sustainability objectives with appropriate corporate actions and performance outcomes.

At presently, Taiwan is undergoing rapid industrialization and is already home to a world-class semiconductor industry (Lin, Panchangam, & Lo, 2009). With serious problems on environmental conservation and sustainable development, the issue of sustainability has become the biggest concern of the semiconductor industry. Recently, the semiconductor industry in Taiwan has suffered different pressures and challenges—from the prohibition of hazardous substances to the Carbon Disclosure Project (CDP) on global warming and sustainable performance ratings. As the example of two well-known semiconductor companies, Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC), have been consistently selected as members of the Dow Jones Sustainability Index (DJSI) since 2001 and 2008, respectively. Apparently the semiconductor industry needs to establish a performance evaluation framework for measuring and improving sustainable performance. Such a framework will provide managers with insights into sustainable strategies. In spite of sustainability is viewed as a distant goal by most industrial and service organizations, Dias-Sardinha, Reijnders, and Antunes (2002) concluded that the barrier to sustainability performance evaluation is the shortage of models, which could be used as performance measurement.

* Corresponding author. Tel.: +886 2 2771 2171x4151; fax: +886 2 2776 4702.
E-mail address: allenhu@ntut.edu.tw (A.H. Hu).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.04.082

Nevertheless, to the best of our knowledge, incorporating the issue of sustainability into the BSC with decision-making method of fuzzy Delphi method (FDM) and the analytic network process (ANP) in formulating a sustainability BSC (SBSC) for the semiconductor industry are never found in previous literature. Most of the early literature has may be limited in describing the process of incorporation of environmental and social aspects into the BSC without using the multi-criteria decision-making (MCDM) technique in constructing a systematic evaluation process.

Initially, early studies have discussed BSC as a possible appropriate conceptual framework for CSR (Figge, Hahn, Schaltegger, & Wagner, 2001; Orssatto, Zingales, & O'Rourke, 2001). Epstein and Wisner (2001) explained the construction of the SBSC framework using two illustrative cases (i.e., the cases of Bristol-Myers Squibb Corporation and Severn Trent Corporation). Their study provided valuable examples on the use of performance measures by leading companies under the four perspectives of BSC. Similarly, Figge et al. (2002) described in detailed the process of formulating an SBSC how environmental and social issues can be integrated into the general management of a business unit. Additionally, Bieker and Waxenberger (2002) modified the BSC to better integrate the corporate sustainability strategies into the core management systems. They illustrated the structural modifications needed to overcome the conceptual shortcomings of the BSC through a pluralistic stakeholder management system. Dias-Sardinha et al. (2002) presented a cascading BSC with a set of aspects considered as reference in performance evaluations with eco-efficiency and sustainability as the main strategic objectives. In their later work, Sidiropoulos, Mouzakitis, Adamides, and Goutsos (2004) incorporated sustainable indicators in a firm's business strategy by modifying the BSC framework through its formulation and implementation at the operations strategy level. To understand the strengths and weaknesses of links between objectives and measurements and between initiatives and achievements, Dias-Sardinha and Reijnders (2005) assessed 13 large companies operating in Portugal through a thematic BSC format. On the other hand, Möller and Schaltegger (2005) proposed an SBSC framework for eco-efficiency analysis, which specifies subsequent information management, data collection, and modeling steps. They embedded eco-efficiency indicators into an SBSC strategy map to estimate and control the appropriate key performance indicators of two major aspects of sustainability, namely, environmental and economic issues. Yongvanich and Guthrie (2006) developed their own "extended performance reporting framework," which included the BSC, social and environmental reporting, and "intellectual capital." Their framework significantly changed the BSC. To integrate measures in the SBSC, Hubbard (2009) proposed a stakeholder-based SBSC conceptual framework coupled with a single-measure organizational sustainability performance index.

As noted previously, the current approaches to the performance evaluation of SBSC may have some methodological deficiencies. Considering the performance appraisal of a number of criteria, Wu, Tzeng, and Chen (2009) suggested that choosing a suitable method to measure the criteria can help evaluators and analysts process the cases to be evaluated and determine the best alternative. Moreover, they claimed that the multiple criteria used in the BSC are more objective and comprehensive than a single one. To solve the failure of the conventional BSC to consolidate various performance indicators, the analytic hierarchy process (AHP) method has been applied (Fletcher & Smith, 2004; Huang, 2009; Leung, Lam, & Cao, 2006; Reisinger, Cravens, & Tell, 2003; Sohn, You, Lee, & Lee, 2003). Nevertheless, AHP suffers from the disadvantages of not sufficiently considering interdependencies (Chung, Lee, & Pearn, 2005) and not allowing for integrated dynamic modeling of the environment (Meade & Sarkis, 1998). As a result, there have been few studies that attempted to utilize the analytic network process (ANP) method in determining the relative weight of criteria in the BSC (Leung et al., 2006; Ravi, Shankar, & Tiwari, 2005) or in the SBSC (Tsai, Chou, & Hsu, 2009). The advantages of ANP include the abilities to incorporate dependencies and feedback using a hierarchical decision network, to represent and analyze interactions, and to synthesize their mutual effects through a single logical procedure (Sarkis & Sundarraj, 2002). Thus, ANP modeling better fits the problem examined in this study and offers the advantage of providing a systematic approach in determining the relative weights of measures in the SBSC.

Regardless of the importance of performance measurement in addressing the issue of worldwide sustainable business and CSR, there is an urgent need to develop an SBSC operational methodology to measure sustainable performance systematically. This will provide managerial insights into the adoption and implementation of sustainable strategies. In view of the significance of incorporating the environmental and social aspects into the SBSC with the MCDM methodology in the semiconductor industry as well as the limitation of previous studies, we propose an evaluation SBSC framework with the FDM and ANP methods. This study has two objectives: to identify the consistent measures of SBSC with respect to environmental and social aspects using the FDM technique, and to develop an SBSC framework of sustainable performance evaluation using the ANP approach. Both objectives are designed to facilitate sustainable management and strategic planning.

The remainder of this paper is organized as follows. Section 2 discusses the SBSC. Sections 3 and 4 introduce the basic structure of the FDM and the ANP methods. Section 5 describes the proposed framework and defines the measures and its weights in the semiconductor industry. Concluding remarks along with the conclusions and future research are given in Section 6.

2. Sustainability balanced scorecard

The concept of SBSC was derived from conventional BSC due to both environmental and social issues as essential pillars of a sustainable business. As pointed out by Figge et al. (2002), sustainability management with the BSC helps overcome the shortcomings of conventional approaches in environmental and social management systems by integrating the three pillars of sustainability into a single and overarching strategic management tool. Therefore, the SBSC may not only help detect important strategic environmental and/or social objectives of the company but may also enhance the transparency of value-added potentials emerging from social and/or ecological aspects and prepare the implementation process of the strategy (Bieker & Waxenberger, 2002).

Considering the differences in organizational sustainability, three approaches have been offered in incorporating sustainability into the SBSC. First, the environmental and social issues can be incorporated into the existing perspectives of conventional BSC (Epstein, 1996). The arrangement of the four perspectives is not modified, which allows incorporating all sustainability issues that have direct relevance to one market, that is, the financial market, the customer market, the supplier market, or the labor market (Möller & Schaltegger, 2005). Second, a fifth non-market perspective can be added to address stakeholder issues. For instance, Figge et al. (2002) increased the number of perspectives to be used by including a fifth non-market perspective. Bieker and Waxenberger (2002) also proposed a fifth perspective called "society." Moreover, Sidiropoulos et al. (2004) added a fifth distinct eco-perspective to the BSC, which is related to issues such as energy and waste consumption, materials use, pollutant emissions, and non-product outputs. In their research, the strategic objectives of the eco-perspective are set according to the concept of industrial ecology,